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Optimized Temporal Error Concealment through Performance Evaluation of Multiple Concealment Features

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Abstract – In this paper we formulate an optimized temporal error concealment approach for H.264 based on the study of the performance of several temporal concealment features that apply to the different steps of the proposed method. Specifically we study how the concealment performance is affected by matching error measures, motion vector candidates and estimation enhancements. We show that the resulting formulated method performs significantly better than other state of the art methods. The proposed approach can prove very valuable to the mitigation of errors typically encountered with video transmission over wireless networks¹

I. INTRODUCTION

Delay sensitive video transmission over error prone networks can suffer from packet erasures when channel conditions are not favourable. Use of error concealment at the video decoder is necessary in such cases to prevent error induced artefacts from rendering the affected video frames visibly intolerable. Moreover, the recent proliferation of consumer devices offering wireless video connectivity makes the topic of error concealment even more relevant.

Temporal error concealment (TEC) methods estimate the motion of missing macroblocks (MBs) and then use this estimated motion to perform motion compensated temporal replacement of the lost MBs. A number of (TEC) methods have already been described in the literature employing new and existing concealment features [1]-[5]. Our aim in this work is to formulate an optimized TEC approach by studying the performance of multiple such concealment features.

The proposed TEC method goes through the following steps. First a list of motion vector candidates is formed for estimating the motion of the missing MB. Then each of the motion vector candidates is tested using a matching error measure. The motion vector (MV) that minimises this matching error is selected as replacement for the missing MV(s) of the lost macroblock. Once a replacement MV has been selected the TEC module proceeds to enhancing the initial estimation. At the end of this process motion compensated temporal replacement of the missing pixels takes place using the resulting MV(s).

In the following sections we study how the performance of the described TEC method is affected when using different matching error measures, motion vector candidates and estimation enhancements. Based on the outcome of this study we formulate an optimized TEC method which is shown to significantly outperform the TEC method employed by the H.264 JM decoder [6].

II. TEMPORAL ERROR CONCEALMENT STUDY

The choice of matching measure plays a central role to the success of the concealment process. Two different criteria for selecting a matching measure are the smoothness criterion and the uniform motion criterion. According to the first one the spatial transition between neighbouring macroblocks should be as smooth as possible. Smoothness is measured as the boundary matching error (BME) defined as the sum of absolute differences along the one-pixel boundary between the recovered MB and the surrounding ones. According to the uniform motion criterion the motion of the missing MB should be similar to the motion of one or more of the adjacent MBs. Motion uniformity is measured as the external boundary matching error (EBME) which is defined as the sum of absolute differences between the multiple pixel boundary of MBs adjacent to the missing one in the current frame and the same boundary of MBs adjacent to the replacement MB in the reference frame. The MV that minimises the chosen matching error becomes the replacement MV. We have studied the performance of these two matching measures for typical standard sequences ('foreman', 'mobile'). For EBME two different implementations were considered: one using a 2-pixel wide boundary; and one using an 8-pixel wide boundary with a raised cosine matrix determining the influence of the boundary pixels on the matching error calculation (WEBME). All 3 test sequences were coded at 1 Mb/s using IDR (1/12) and P frames with a slice size equal to 536 bytes and dispersed FMO with two slice groups. Results are shown in terms of the average PSNR of the corrupted P frames after concealment, for the cases of the coded bit stream being affected by random packet errors (slice erasures) at rates of 1%, 2%, 4%, 10% and 20% (results averaged over 10 error patterns). Note that only P frames were corrupted. The graphs of Fig. 1 suggest that using an external boundary matching measure can lead to substantial improvements in concealment performance (up to 3 dB) with EBME being favoured due to its smaller complexity.

We now focus on the list of motion vector candidates which should consist only of those MVs that enhance the concealment performance. Starting with a basic list consisting of the zero MV and the 4-neighbours of the missing MB we study the performance enhancement offered by additional MV candidates using EBME as the matching measure. The additional candidates are the 8-neighbours of the missing MB (i.e. corner MBs as well), the average of those, the MV of the collocated MB in the previous frame and finally the 8-neighbours of this collocated MB. The encoding parameters are similar to the matching measure study but without use of

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FMO. The graphs of Fig. 2 show that with the exception of the average MV, adding one (set of) candidate MVs to the basic list of candidates improves the performance by up to 0.4 dB. The average MV does not seem to offer any benefits. The full list of candidates (+All) gives a further (small) improvement compared to the best single-candidate performance.

Finally we investigate possible further enhancements to the initial estimation of the replacement MB. Such enhancements include the use of overlapped block motion compensation (OBMC) for the replacement of the missing pixels and motion refinement of the winning and other candidate MVs. OBMC for concealment implies use of more than one reference MBs (and hence more than one estimated MVs) for the replacement of damaged pixels. Motion refinement implies that the selected MV is used as a starting point for a motion estimation process that looks for better MV replacements using EBME as the matching measure. For complexity reasons motion refinement was implemented following a 3-step search approach with the search range being 32 pixels and matching done at half pixel resolution. For OBMC the damaged MB is divided into four 8x8 blocks for each of which 4 replacement signals are formed using the winning MV, and the MV of the corresponding adjacent 8x8 blocks of the 3 neighbouring MBs. The 4 motion compensated replacement signals are then blended according to a raised cosine weighting matrix that favours the winning MB for replacing pixels close to the centre of the missing MB. The motion refinement performance is studied for the case of refining the winning MV (WMVR), and the zero MV (ZMVR) for concealing corrupted P and I frames (Fig. 3). The performance benefit is very small (if any) for P frame concealment. In I frames however which lack motion information, motion refinement proves a useful step in the TEC process offering up to 1.8 dB at higher PERs when added to a TEC approach that employs the zero MV, the MVs of the collocated MB and its 8-neighbours in the previous P frame for concealing corrupted I frames. OBMC takes place once the replacement MV has been selected (a candidate or a refined MV). The performance with OBMC for concealing corrupted P frames is shown in Fig. 4, with observed PSNR improvements of around 0.3 to 0.5 dB.

Based on the studies presented in this section we formulate the temporal concealment approach shown in Fig. 5.

III. CONCLUSIONS

This paper described an optimized TEC approach based on the study of several concealment features that apply to the steps followed in the suggested method. The overall performance of the proposed method relative to that employed in the JM decoder is shown in Table 1 (average PSNR across all error patterns) for a number of sequences and a PER of 10%. The coding and testing parameters remain as stated in section II.

PSNR(dB)	Foreman	Bus	Flower garden	Mobile
JM	33.26 (34.59)	29.42 (30.95)	26.82 (28.09)	26.19 (27.51)
Proposed	35.07 (36.03)	31.60 (32.69)	29.23 (29.85)	28.89 (29.52)

Table 1: PSNR results of the proposed TEC method vs. JM. Values shown are for concealed P frames and in parenthesis for the whole sequence (PER 10%).

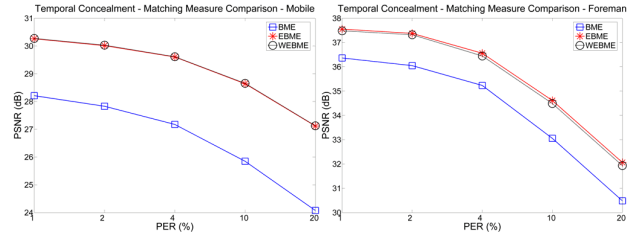


Fig. 1. Performance study of matching measures.

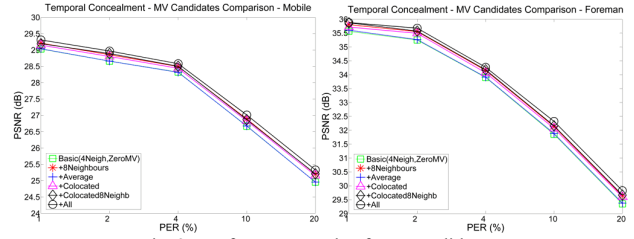


Fig. 2. Performance study of MV candidates.

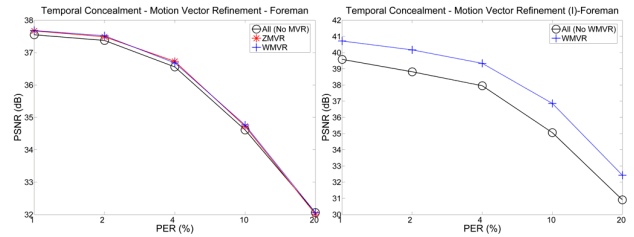


Fig. 3. Performance study of motion refinement (P left, I right).

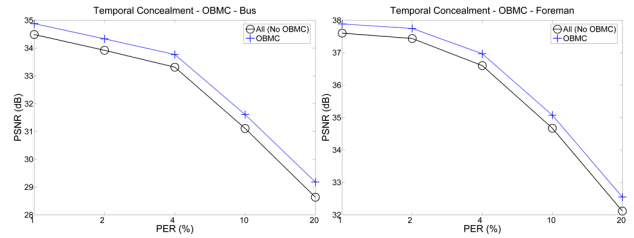


Fig. 4. Performance study of OBMC.

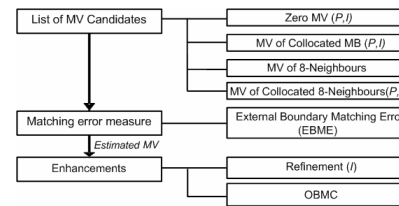


Fig. 5. The proposed temporal error concealment approach.

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